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# The Challenges of Teaching Product Configuration and Detailing Course to Heterogeneous Background Students

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**Abstract:** Product configuration and detailing in product design demands understanding various components and their interactions. Novice design students from diverse backgrounds find it challenging due to distinct thinking capabilities, knowledge, and motivations. We restructured the course to address these challenges, introducing strategic assignments and tools to enhance learning. While a small sample size limits our findings, our pedagogical approach offers a framework for broader implementation and refinement.

*Keywords: Configuration Design, Detailing, Heterogenous Background Students, Teaching Aid, Design Pedagogy*

## 1 Introduction

In recent decades, the landscape of design education in India has undergone a significant transformation, witnessing a remarkable surge in the establishment of design schools. The count has surpassed 1000 institutions across both government and privately funded sectors, reflecting the growing interest and investment in design disciplines within the country. A key facet of this evolution lies in the Master of Design course, a program that attracts students from diverse academic backgrounds such as engineering (across all streams), architecture, various design disciplines, and fine arts (Shende and Das, 2015). This amalgamation of students from varied graduation backgrounds enriches the educational environment, fostering a myriad of perspectives crucial for the holistic development of design professionals, particularly in the realms of ideation and post-ideation phases of product design.

The first year of the post-graduate program is pivotal in assimilating these heterogeneous students onto a common platform. Within the Product Design curriculum, core courses aim to provide a foundational understanding across key areas of design. These include Form Studies, Material and Processes, Product detailing, and Ergonomics. Complementing these are additional courses encompassing design thinking, methodology, sketching, as well as those delving into art, design history, and sociology. Among the core courses, Product detailing stands out for its critical role in enhancing product reliability and performance, reducing ambiguity, and defining essential processes at the inception of design projects.

The paper focuses on the methodologies employed in teaching the Product detailing course within this diverse educational context. The course was delivered to a cohort of 15 students enrolled in the first year of the MDes-product design program. Within this cohort, there was a gender-balanced representation, with 6 female and 9 male students. Their academic backgrounds further reflected the diversity inherent in the program, with 8 of them holding undergraduate degrees in engineering or architecture, while 7 hailed from fine art and fashion design backgrounds.

An observation emerged regarding the distinct approaches adopted by students in tackling the challenges presented by the Product detailing course, largely influenced by their respective academic backgrounds. Engineering students showcased a predisposition towards technical thinking, leveraging their familiarity with sectional drawings, detailed drawings, and orthographic views. Conversely, students with architecture backgrounds demonstrated a penchant for lateral thinking, while those from fine art and fashion design backgrounds gravitated towards aesthetics, sometimes struggling with the technical aspects of product performance.

In the field of product design, the process of concept selection for determining product detailing holds immense significance, as it lays the groundwork for all subsequent design activities. Chen and Lin (2002) underscore the necessity for continuous refinement of product concepts at the early stages of design, recognizing the fluidity and subjectivity inherent in design processes.

In light of these observations, this paper proposes a systematic, step-by-step approach to teaching product detailing, leveraging assignments of increasing complexity to bridge the gaps in understanding among students from heterogeneous backgrounds. The overarching research aim is to evolve a pedagogical framework that facilitates a common ground, enabling students to navigate product configuration and detailing with proficiency, regardless of their academic origins.

Through this endeavor, we endeavor to contribute to the cultivation of a new generation of design professionals equipped with the interdisciplinary skills necessary to thrive in an increasingly complex and interconnected world.

## 2 Component knowledge

Understanding of components plays a crucial role in the design of product configurations, as it informs the terminology used to represent various component types. Typically, these terms are associated either with fixed components, characterized by predefined specifications and values, or with designed components, which can acquire specific parametric values (Wielinga and Schreiber, 1997). To familiarize students with components, they were introduced to material libraries and online resources. Moreover, the assignments they received emphasized the importance of designing components to fulfill specific functions and enhance the product's value, discouraging reliance on pre-existing fixed components.

To help students understand how to examine products closely, a simple activity was done. Students had to choose a basic product with at least two parts. They then looked at each part carefully, made a list of them, and thought about how they work together. This activity helped students see how parts fit together and understand how products are made. After that, students were asked to draw pictures showing how the parts fit together and what they look like inside. It was observed that students from engineering and architecture backgrounds demonstrated familiarity with sectional drawing techniques, whereas those from fine art and fashion design backgrounds approached this task as a novel learning endeavor. Figure 1 illustrates a cross-sectional representation crafted by a fine art student, exemplifying disparities in proficiency levels.

Figure 1: Clasp section drawing by a student having fine art background

Acknowledging these disparities, further instruction on section drawing techniques was provided through the utilization of case studies and tangible props, as depicted in Figure 2. These supplementary pedagogical resources aimed to equip students, particularly those less versed in technical drawing concepts, with practical guidance and visual aids to augment their comprehension and application of section drawing methodologies. Through the implementation of these targeted pedagogical interventions, students were afforded an enhanced capacity to navigate the complexities inherent in product configuration design and detailing, thus fostering an inclusive learning milieu conducive to the accommodation of diverse academic backgrounds, learning modalities, and experiential repertoires.

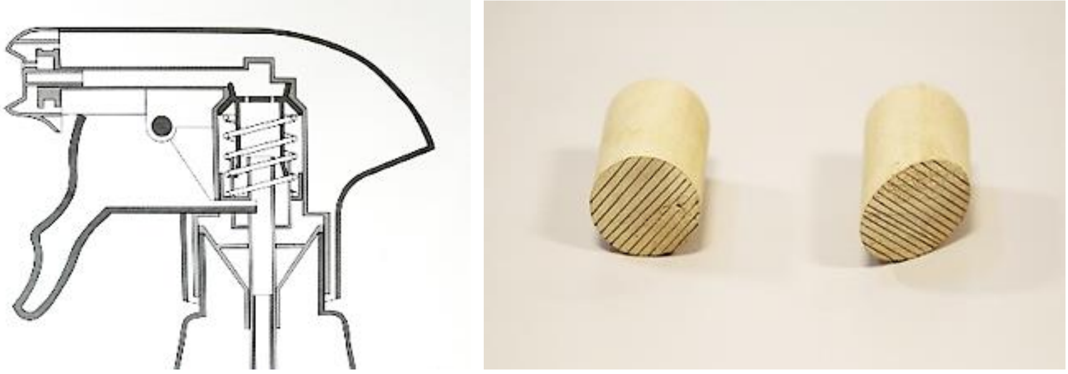


Figure 2: Sample section drawing and Props

### 2.1 Representation of product design and its implications

Product concepts undergo refinement during the initial stages of design and are frequently subject to alteration. To streamline the design process, engineers aim to generate product configurations and select high-performance configuration ideas while minimizing complexity (Wei et al., 2015). However, in India, industrial designers are expected to propose product configuration ideas and collaborate with engineers to develop them further. Designers prioritize aspects such as usability, modularity, aesthetics, sustainability, lifecycle assessment, materials, and costs in their approach to configuration problem-solving, which is highly valued.

Nevertheless, the influx of students from diverse backgrounds into design programs in India has added complexity to teaching configuration design (Shende and Das, 2015). Students' responses and interests vary across topics, reflecting differences in their levels of understanding. These disparities pose challenges in comprehending this specific course, which demands a particular type of thinking ability. The course entails visualizing components' orthographic views, configurations, and assembly details while designing a product.

Cross-sectional drawings play a crucial role in effectively communicating functional couplings and generating feasible alternatives with clarity. Despite receiving clear instructions and training on section drawings, many students struggle to visualize details, impacting their confidence and approach to handling configuration design problems. To address this gap, the course is structured to bring all students to a common platform through strategically planned assignments, specially designed cross-section props, and everyday objects. These measures aim to enhance students' grasp of section thinking fundamentals.

## 3 Methodology adopted

*Aim:*

The aim is to assess and compare the product detailing abilities of industrial design students from diverse educational backgrounds. This is achieved by conducting a series of assignments to evaluate product detail problem-solving approaches, identify potential disparities among students, and assess the effectiveness of current pedagogical methods in addressing diverse student needs.

*Objectives:*

- To evaluate the product detailing design abilities of students with varied educational backgrounds.
- To identify any differences in problem-solving approaches among students from heterogeneous backgrounds.
- To assess the extent to which current pedagogy meets the diverse educational needs of students.
- To investigate the effectiveness of progressive and peer learning approaches in enhancing students' design skills.
- To gather insights into students' abilities to visualize and resolve details in product design across different levels of complexity.

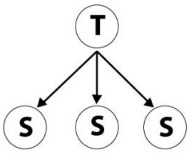
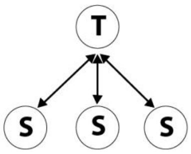
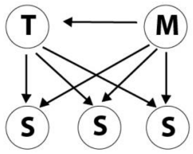
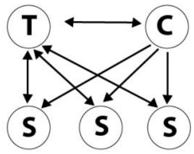
*Impact of Student Background on Learning Outcomes:*

Students from engineering backgrounds are further distributed into specific streams such as Mechanical Engineering, Production Engineering, Electrical Engineering, Metallurgy, and Civil Engineering. Among these, students from Mechanical and Production Engineering backgrounds are often more adept at solving product detail problems due to their prior exposure to courses like linkages, theory of machines, materials and processes, and trusses. Conversely, students from other engineering disciplines may have limited knowledge in these areas.

Students from architecture backgrounds are divided into Pure Architecture and Architecture and Planning streams. It is observed that students with an architecture background have a balanced learning of technical and aesthetic aspects. However, students with a planning background seem to have less technical learning in their undergraduate program, which affects their approach to problem-solving.

Furthermore, the thinking pattern of students are often influenced by their respective backgrounds academic culture, as summarized in the Table 1. The relationship dynamics between engineering students and their teachers are typically one-way especially in Indian Engineering education, contrasting with the more interactive relationship seen between teachers and students from Fine Arts backgrounds. Architecture students share a similar relationship dynamic with Fine Arts students, emphasizing creativity and contextual understanding. This encourages fact-finding and divergent thinking among architecture students. In marketing, the approach varies across sectors, often focusing on producing market-ready products, limiting problem-solving attitudes

Table 1. Understanding thinking pattern of students' w.r.t. their background

| Engineering | Fine Arts | Design (fashion design) | Architecture |
|---|---|---|---|
|  |  |  |  |
| Imagination Power suppressed | Imagination Power is superbly enhanced | Solving complex problem with a very practical attitude to suite market demand. | More explorative attitude |
| Only conventional method or idea to be followed. | Freedom to choose any topic and method | Exposed to exhibitions | Imaginative |
| Significantly less extrinsic motivated | High extrinsic & intrinsic motivation | Imagination is suppressed for new idea generation. | Thinking in Macro. |
| High on practical thinking | Practical thinking is suppressed | Focused to market | Contextual thinking |

T- Teacher, S- Student, M-Market, C-Context (based on Gillies 2008)

### *Methodology:*

The methodology employed was based on prior experiences and the scarcity of literature on product detailing from an industrial design perspective. This allowed for a direct assessment of product detailing ability, aiding in the identification of any disparities in problem-solving approaches among students from heterogeneous backgrounds and evaluating how current pedagogy accommodates the needs of diverse students. The experiments were conducted over a three-week period as part of a course involving 15 students, comprising 6 females and 9 males. During group formation, gender balance was ensured, resulting in two groups: Group 1 (G1), consisting of students with engineering and architecture backgrounds, and Group 2 (G2), comprising students with backgrounds in fine art and fashion design. The assignments are designed based on the fact that students with different backgrounds affect the thinking patter as described below.

The study began with a warm-up exercise and proceeded to three assignments focusing on simple, complex, and modular product designs. Each assignment was designed to facilitate progressive and peer learning:

Assignment 1: Simple Product - Designing a simple product with a maximum of 4 components.

Assignment 2: Complex Product - Designing a complex product with more than 4 components, addressing load, material, and detailed characteristics.

Assignment 3: Modular Product - Resolving details of a modular product with numerous features, emphasizing visualization of section drawings and generating non-redundant solutions for details and component matching.

Assessment of the assignments involved collecting and analyzing student responses using the consensual assessment technique. Three expert faculty members in product design were selected to rate the ideas on a scale of 1-7.

**Simple product (Assignment 1):**

Redesigning a tape dispenser was selected as the topic, based on the commonly seen problem of loading and unloading a tape roll. Students were provided with readily available tape dispenser samples (Figure 3) and tasked with generating ideas for tape dispensers featuring innovative configuration designs. They were given freedom in terms of material and process constraints.

Two of the designs created by students are depicted in Figure 4.

Figure 3: Sample tape dispensers shown to students

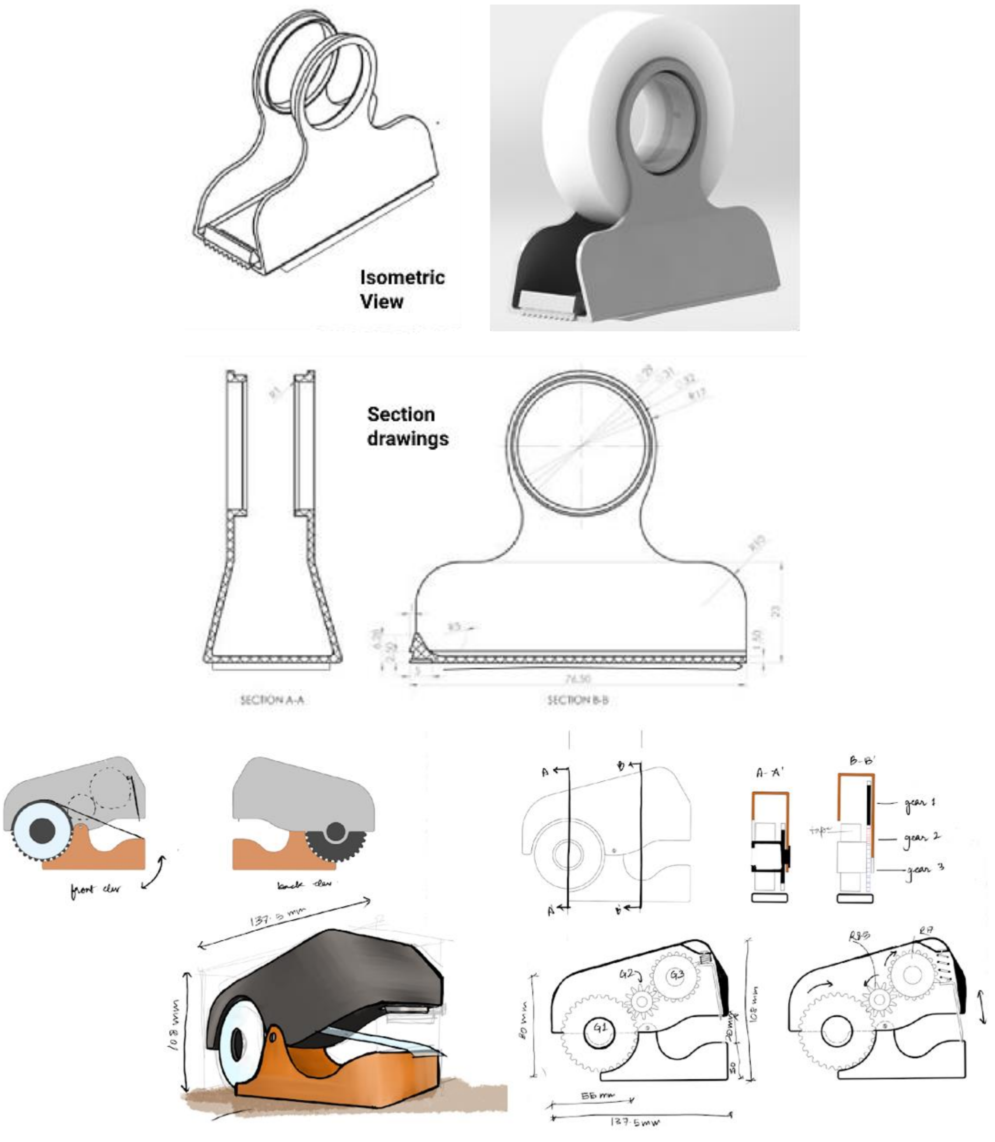



Figure 4: Student's configuration and detailing solutions for tape dispenser

**Complex product (Assignment 2):**

A more complex product involving motion and a sense of load distribution was selected. Students were asked to study the bottom half of a swivelling chair and redesign the product configuration details. The students disassembled an existing chair to study, drew the components, and then worked on the configuration design and details for a new idea. In this experiment, the constraint was to use steel metal tubes and all metal-related processes.

The rules for discussion amongst students were planned strategically. Engineers could discuss with architects, architects with fine arts and fashion design students, and they would further discuss ideas with engineers. This strategy aimed to have mixed background inputs during the ideation stages.

**Modular product (Assignment 3):**

A recumbent tricycle was selected for this exercise. It is a complex product with motion and many components to configure. In addition to that, the students did not have a sample product for any physical references. Students had to research through internet and redesign the recumbent bicycle using bicycle parts readily available in the market.

The strategy was to break the product into smaller modules (Newcomb et al., 1996). The product is broken into four modules: the pedal hub and chain module (M1), steering and brake module (M2), seat module (M3), and frame module (M4). Each module had a set of components independently functioning, and in the end, all modules were interdependent to form a functional coupling when assembled. The modules M1 and M2 were assigned to the G1 group (group having engineers and architects), and M3 and M4 were assigned to the G2 group (Group with fine art and design background students). Students studied the module-wise components and then solved the configuration design problem for the particular module. Groups G1 and G2 also had to follow a protocol of consulting each other for any decisions as established during assignment-2. The design project involved conceptual considerations with the shapes, ergonomics, aesthetics, and all functional couplings, including configuration component design.

## 4 Preliminary analyses of the observational data and its results

In order to analyze the data, a consensual technique was employed. A set of design professionals evaluated the outcome of the assignments in the form of comments. The qualitative analysis of experiments was compiled from the collected data and is presented in this section. However, no attempt was made to validate the results using statistical tools.

**Simple product (Assignment 1):**

In this case, the idea was to determine how the heterogeneous background students respond to the configuration design, the overall feasibility of details, and the development of a simple product. Table 2 shows the comparison between G1 and G2.

Table 2. G1 and G2 comparison of the assignment 1

| Group | Configuration design | Feasible alternatives | Section drawings | Detailing Idea Development |
|---|---|---|---|---|
| **G1** (Students with engineering and architecture background: 8 no.) | The students generated mundane configuration design solutions. | Feasibility of details were high | Representation of configuration design through section drawings was satisfactory | Idea development was impressive |
| **G2** (Students with fine art and fashion design background: 7 no.) | The students generated mundane configuration design solutions. | Shows low feasible alternatives | The students were finding difficulty to visualize the sectional views of the details | Idea development was tough. |

*Observation:*

Students from diverse backgrounds were equally capable of coming up with basic design ideas. However, they showed differences when it came to developing practical alternatives. Engineering and architecture students had an edge due to their prior knowledge of materials and processes, unlike those from fine art and fashion design backgrounds. Moreover, variations were observed in how they portrayed sectional drawings and evolved their ideas. In conclusion, students' backgrounds played a significant role in influencing their responses.

**Complex product (Assignment 2):**

This experiment aimed to determine how the heterogeneous background students respond to the configuration design when they work in a small group and derive inference from the mixed background group. Indirectly, the students of all backgrounds were part of the ideation process.

Table 3. G1 and G2 comparison of the assignment 2

| Group | Configuration design | Feasible alternatives | Section drawings | Detailing Idea Development |
|---|---|---|---|---|
| **G1** (Students with engineering and architecture background: 8 no.) | The configuration design ideas were incremental in nature. | Feasibility of details were high | Representation of configuration design through section drawings was satisfactory | Idea development was perfect |
| **G2** (Students with fine art and fashion design background: 7 no.) | Few configurations design ideas were novel | Feasibility improved to a certain level | Section drawings improved moderately. | The development of idea improved. |

*Observation:*

Students with art and design backgrounds (G2) could use analogies for configuration design, which shows a significant shift in concept generation compared to the students with engineering and architecture backgrounds (G1). Figure 6 shows the example of the work by G2 where they used analogy like clutch pencil mechanism and lateral approach of pipe joining by pinching the end and fixing in a slot.

The feasible alternatives, section drawings and idea development of the students in G1 matured as can be seen in figure 5. The lateral exploration is visible in the figure where students explored different materials and processes to create castor chair base using metal tubes, sheets and casted components. Due to constant interaction between the mixed background students, G2 students improved their skills in feasibility, section drawings and idea development.

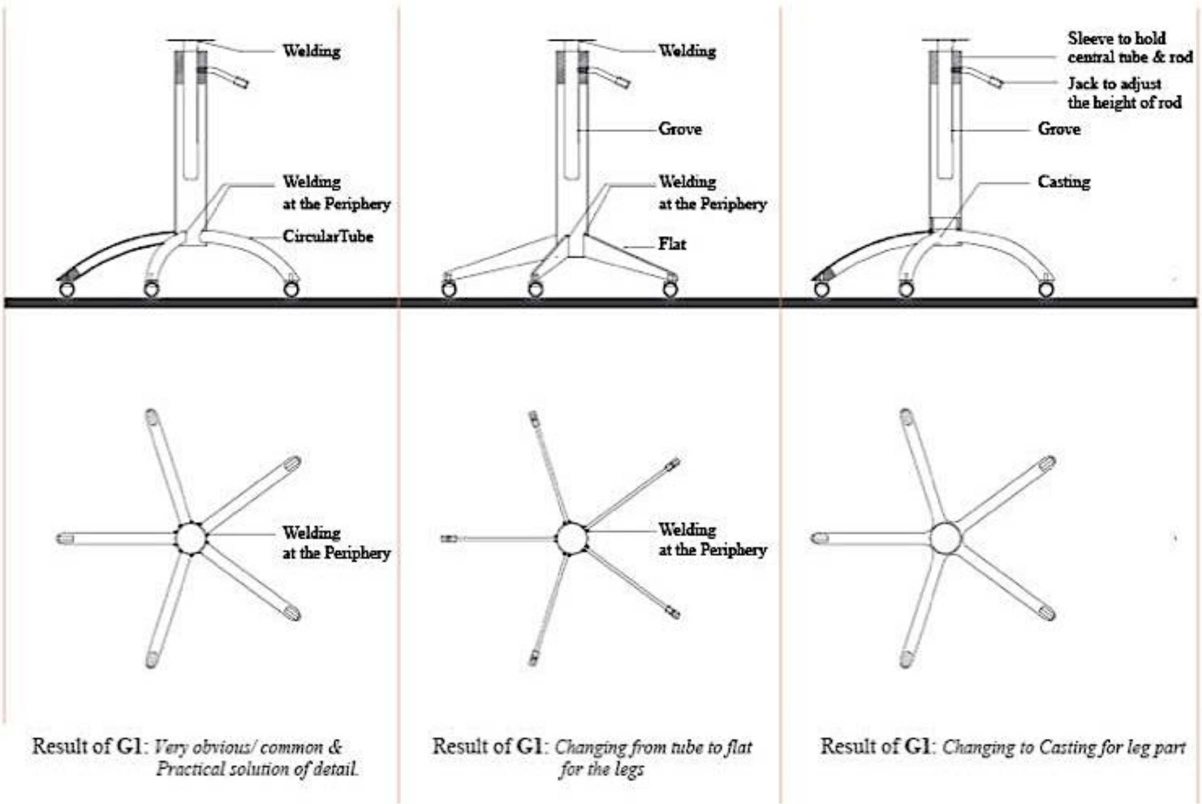



Figure 5: G1 Student's configuration and detailing solutions

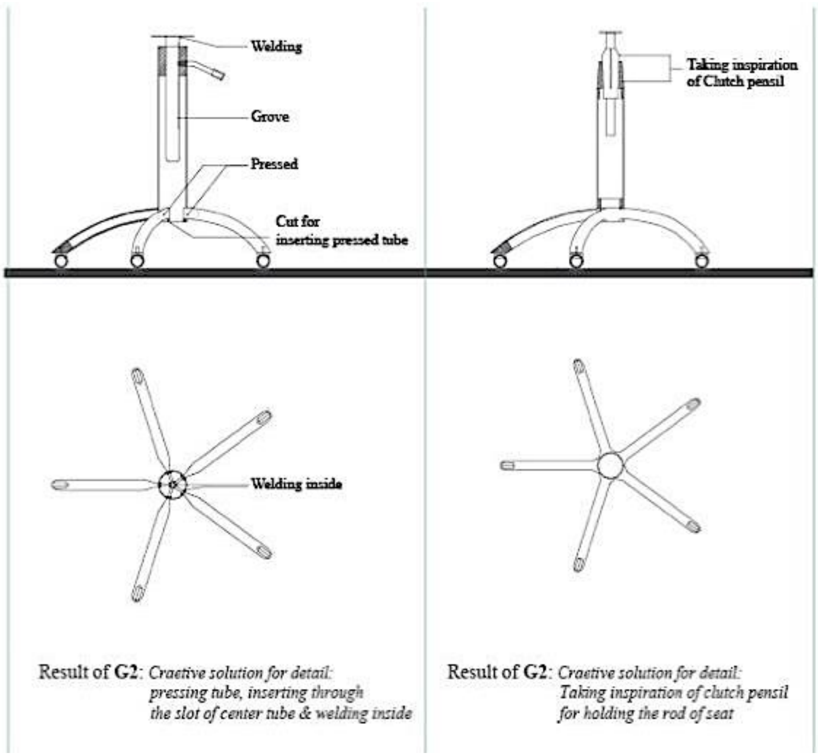



Figure 6: G2 Student configuration and detailing solutions

**Modular product (Assignment 3):**

The module strategy worked well as each group focused on the particular modules. The continuous interaction between G1 and G2 had advantages in sharing the configuration design details, discussing the process of making, the interdependency and interconnection of all modules, and forming the functional couplings of all modules. The students shared the section drawings and improved them continuously. The students collectively brought all the required parts based on their tricycle configuration design. The students were encouraged to use CAD modelling and simulation to realise it.

*Observation:*

The students with all backgrounds could participate and perform inclusively. They differed in the feasibility aspect but quickly resolved through interactions. The decision-making was consensual, making them interdependently solve the configuration problems. The students who needed to improve on the representation of section drawings could learn to draw better through the help of better students. The strategy enabled peer learning and consensual decision-making, which is crucial in the design environment. Finally, students solved configuration design problems and made a 1:1 prototype for testing, as shown in Figure 8.

In this assignment, alongside guidance from the instructor and contextual cues, the methodology fostered and augmented peer learning through student-student interaction. The pedagogical framework adopted a non-linear structure, wherein both the instructor's guidance and contextual elements featured prominently throughout the process, thereby fostering sustained interaction among students. In comparison to Gillies' (2008) work, Figure 7 illustrates the interaction model within this specific context.

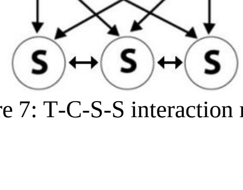



Figure 7: T-C-S-S interaction model


Figure 8: The module-wise and final assembled design by G1 and G2 for Assignment 3

## 5 Discussion

Based on the above assignments and their outcomes, it was observed that students initially exhibited a need for improvement in sectional thinking at the outset of the course. However, over time, their capacity to represent sections improved notably through engagement in peer learning activities. During the initial warm-up exercise, a majority of students overlooked considering the thickness of part walls in their section drawings. Nevertheless, the acquisition of component knowledge and exposure to case study examples regarding section drawings contributed significantly to enhancing their understanding of the subject matter. The structured sequence of three assignments facilitated a gradual learning process. Ultimately, regardless of their diverse backgrounds, all students demonstrated comfort in solving and communicating configuration design problems and functional couplings. The utilization of purpose-designed tools and props effectively enhanced their ability to visualize cross-sections in three-dimensional form. Assignment 1, while straightforward, required more time due to students' initial exposure to configuration design challenges. Subsequently, the second assignment demonstrated improved efficiency. Many students acquired the skill of generating detailed ideas and learned to concentrate on specific points requiring resolution. The significance of teamwork and its impact on peer learning became evident through the completion of the third assignment. The module strategy, wherein Groups 1 and 2 worked independently yet collaboratively, underscored the importance of functional couplings in design problem-solving. This observation aligns with the findings of Nelson et al. (2010), emphasizing the inevitability of peer learning and collaboration in addressing complex problems. Furthermore, students' comprehension of the interdependency of independent components was reinforced throughout the process, facilitating their attainment of a common understanding.

**Limitation of the study:**

The study encountered a notable limitation due to the restricted number of students involved, with only 15 participants enrolled in the course. Consequently, the findings derived from this study cannot be readily generalized to broader student populations. Moreover, the nature of the evaluation leaned towards qualitative analysis rather than quantitative measurements. Despite these constraints, the study proved invaluable in shaping a pedagogical approach for future iterations of this course. The insights gained from this qualitative evaluation have provided a solid foundation upon which to develop and refine teaching methodologies, thereby enhancing the educational experience for subsequent cohorts of students.

## 6 Conclusion

The study reveals that students' backgrounds play a significant role in their responses to specific course assignments, such as Product Configuration and Detailing. Targeted training and strategic task planning can help students overcome knowledge gaps arising from their varied backgrounds and build confidence in their abilities. The integration of supportive tools and meticulously designed assignments within such courses effectively enhances students' proficiency in areas where they may lack expertise. The aim was to enable students to navigate product configuration and detailing learning proficiently, which could only be achieved through cooperative methods and peer learning through collaboration. The Teacher-context-student-student (T-C-S-S) interaction significantly improves problem-solving abilities among all students. Such approaches need to be encouraged and incorporated into engineering and design curricula. The CDIO Initiative emphasizes fundamental principles within the framework of Conceiving, Designing, Implementing, and Operating systems and products. While prioritizing technical fundamentals, it also prepares students for active roles in system product development, with CDIO activities integrated throughout the curriculum. It is recommended to incorporate T-C-S-S approaches between designing and implementing activities.

According to a survey report by the British Council in India (2016) on the future of design education in India, most institutes have already established learning outcomes for their courses, and only a small portion intend to do so in the future. These institutes promote problem-based learning and emphasize peer learning among students. Despite ongoing efforts to improve design curricula, there is inconsistency among institutions, as some still maintain traditional silo-based approaches. Thus, reporting the new pedagogical approaches and assignments can help upcoming design institutes to learn from each other and evolve design curriculum collectively.

The findings underscore the importance of conducting further research across various schools and institutions to determine if similar patterns emerge. This subsequent investigation should initially focus on Product Configuration and Detailing skills before potentially expanding to incorporate additional foundational industrial design knowledge. Gaining a quantifiable understanding of how students from diverse backgrounds learn across different institutions will aid in identifying optimal learning environments and pedagogical approaches for students with heterogeneous backgrounds. This knowledge is essential for strengthening the skills of industrial design students as they transition into professional practice.

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